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JANUARY 23RD, 1854.

THOMAS ROMNEY ROBINSON, D. D., PRESIDENT,
in the Chair.

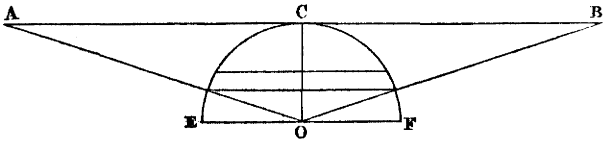
ON the recommendation of the Council it was Resolved, that the following By-Law be adopted:—

"That no Member whose subscription shall be due on the 30th November in each year shall have the privilege of voting on or after that date, until his subscription be paid up."

The President read the following Paper on a new method of measuring the angular aperture of the objectives of microscopes.

"Shortly after the commencement of those improvements which have made the microscope such a powerful instrument of research, it was observed that complete freedom from aberration and high magnifying power are not sufficient alone to give perfect vision to a certain class of objects; but that these essential qualities must be combined with a large angle of aperture. The scales of Lepidoptera and Thysanura, and still more the siliceous valves of certain Diatomaceæ, are well-known examples of this fact; and to the use of them as tests we mainly owe the astonishing progress which has lately been accomplished in this department of optical art. Several among us remember the admiration which was excited by the first objectives of 20° or 30° aperture, and which became still more enthusiastic when Ross carried this element to 60°, which was considered a *ne plus ultra*. But as objectives were improved, more difficult tests were found which stimulated progress, till angles of 170° and upwards have been obtained, by this great optician with us; by Nachet in France; and Spencer in America. The combination of science and operative skill which is required to produce such miracles of art cannot be too much praised; and up to a certain point it must be confessed, that the performance of these objectives corresponds fully to their promise. It seems to me, however, that in the extreme cases to which I refer, there is not unfrequently some defect of construction which prevents them from being quite as effective as their great aperture might lead us to expect.

" The effect of *angular* aperture is merely an increase of illuminating power* analogous to that of *linear* aperture in a telescope. Let O be a point of an object seen by an objective whose anterior surface is AB. This point, in the case of a test object, may be considered as self-luminous and equally so in every direction. Therefore, the light which it sends to the objective is measured by the portion of the hemisphere ECF, which is included by the cone AOB. If all that light came to the eye, the illumination would be measured by $4\,\pi\,\sin^2\frac{\theta}{2}$, θ being = AOC; but this is never the case. The object is almost invariably covered with a piece of thin glass, both whose surfaces reflect a portion of the light if it be mounted dry, one only if it be in balsam.† A



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[*] It does not depend on greater convergence of the rays; when the disked stop, hereafter described, was placed in a quarter 105° aperture, the ring of the objective left free showed a test object just as the same illuminating power of an ordinary one would do.

[†] For objects in balsam no light can escape at a greater incidence than 46°; therefore, notwithstanding the absence of the first reflexion, they will be less illuminated than in the other way. It is in fact equivalent to reducing the aperture of the objective below 100°, as far as illumination is concerned, though a much larger one may be required to take in the pencil; and it should not be used when it is desired to see details of the utmost minuteness.

similar loss occurs by the reflexion at the first surface of the objective, which, like the cover, is plane; and at all the others which are uncemented. To compute these last would require a plan of the objective's construction; but as I only wish to give an approximate estimate of the effect of aperture, and as the incidences there, and consequently the reflexions are comparatively small, it is sufficient to consider the loss of light at the first surface and at the cover alone. Further, as the first lens is *dense* flint glass, and the cover of the ordinary sort, the loss by the two reflexions may be assumed as equal to that caused by the single one of the lens. Taking for the dense flint, $\mu = 1{\cdot}67$, we can compute, by the help of a well-known formula of Fresnel, I the intensity of light transmitted at the incidence θ: the element of the hemisphere which transmits this light $= 2\pi . \sin \theta . d\theta$; and therefore, the quantity of light transmitted by the first surface is—

For an uncovered object, ... $2\pi \int I \sin \theta d\theta$.

For a covered, ... $2\pi \int I^2 \sin \theta d\theta$.

As yet, however, I have never seen an objective which, when compensated for uncovered objects, has a very large angle; and in some of them the difference is very great. No. 4, when set to the mark "uncovered" (which, I presume, was correctly placed by its maker), gave only 70°. From the short working distance which is inseparable from a large aperture, it is not a desirable mode of using them, as there is a great chance of the lens being sullied.*

"The following Table gives a few values of these angles, omitting the factor π.

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* This reasoning assumes that the light transmitted through the cover is not less reflexible that it was before transmission.

Aperture.	$I = 1$.	Uncovered.	Covered.	First Surface curved $\theta' = 75°$.
20°	1·74	1·62	1·53	1·52
40°	6·91	6·47	6·07	6·06
60°	15·35	14·37	13·47	13·46
80°	26·81	25·07	23·45	23·46
100°	40·93	38·12	35·52	35·60
120°	57·30	52·90	48·86	49·21
130°	66·16	60·38	55·33	56·14
140°	75·40	67·93	61·89	63.05
145°	80·13	71.25	64·70	66·39
150°	84·93	75·23	67·26	69·69
155°	89·79	78·09	69·70	72·83
160°	94·69	81·68	71·54	75·89
165°	99·63	84·77	73·11	78·73
170°	104·60	86·56	73·97	81·52
175°	109·59	88·43	74·33	84·17
180°	114·59	88·60	74·52	86·84

“These numbers (which, from neglecting the remaining reflexions, must give rather too much weight to the larger apertures) show clearly that, especially for covered objects, nothing is gained above 150° at all commensurate to the difficulty of constructing such objectives. But in addition to this, I wish to call attention to the fact, that the whole of these great apertures is not in every case thoroughly effective.

“The mode of measuring them which is commonly used is that given by Mr. Lister, in which the microscope is attached to the alidad of a circular instrument, with its objective over the centre, and directed towards a luminary at some distance. Looking into it, the field is filled with light, which, on turning the alidad, is seen to have a circular boundary: if this be brought from each side to the middle of the field, the intercepted arc is the aperture.* For objectives of considerable focal length, this process is unexceptionable; but does not succeed so well with those of high power and aperture; the boundary is very faint, and sometimes difficult to observe. This is especially the case if the light be not uniformly diffused, or if the boundary be irregular; and if there be any false light, it is impossible to distinguish it from that which really contributes to vision.

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* When the aperture is very large, there is a sluggishness in the apparent movement of the boundary, which makes me have some doubt of the accuracy of the process; it seems almost stationary in No. 6.

"This was strikingly the case with an objective which lately came under my examination; it was a sixteenth, said by its maker to be 160°, and in which light actually was visible to that extent, though not satisfactorily. When, however, it was tried on the Pleurosigma Fasciola, it could not (even with the most oblique illumination that Amici's prism can give) be made to show this test better than a twelfth from the same artist, whose aperture is only 129°. This unexpected result made me seek some mode of measurement which would not only give the angle of aperture, but also show how the light was distributed; and the following seems to fulfil both these requirements.

"As a lucid point in the focus of the objective sends out from the eye-piece rays nearly parallel, so light sent in the opposite direction through the microscope will converge at that focus, and then diverge in a cone whose angle equals the aperture of the objective. If this cone be intercepted at right angles to its axis by a screen, and the diameter of its section, together with the distance of the screen from the surface of the objective, be carefully measured, they give the aperture. If S be the diameter of the section, D the distance, O the diameter of the objective, and I that of the image of the luminary used which is formed in its focus:

$$2 \tan \frac{A}{2} = \frac{S + O}{D} \times \frac{O}{O \mp I},$$

the upper sign being used if the section is measured within the penumbra, and *vice versâ*. In my practice I was so small that the second factor is = unity, for I directed the light of the sun into the instrument by means of the reflecting part of a solar microscope, and not only got measures with extreme facility, but had at once a beautiful map of the objective's light-territory.

"No. 1. As a term of comparison I began with a quarter of known excellence. The section was a neat circle nearly uniformly bright, surrounded by a penumbra also equally well-defined. The measures were taken to 0·005, and they gave (denoting their results by A', and those of the ordinary process by A),

$A' = 80°, 8$, ... $A = 80°, 75$,*

which for such determination may be reckoned identical.

"No. 2. The sixteenth just mentioned presented a very different appearance. The central part of the section was bright, with a jagged outline formed by dark bands spreading outwards in the direction of radii very far; so far indeed, that I could not trace their end, or see any boundary of the section. Between these bands were stripes of light, but so mottled and confused as to satisfy me that this part of the illumination could not give distinct vision. Looking directly at the objective, light could be seen even at an obliquity of 85°. The bright part within the radial shadows was not exactly circular; but, taking an average diameter, I found for the part which seemed to me alone likely to give effective vision,

$A' = 110°,8$, ... $A = 160°$.

"No 3. The twelfth, also referred to, is much better: the section was toothed all round like a wheel, but to no great extent, and a defined boundary was visible. The diameter of the bright part gave

$A' = 109°, 3$, ... $A = 129°, 0$.

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* The compensation of these lenses was adjusted by the Pleurosigma Angulata.

This explained the equal performance of these objectives, by showing that in fact the effective portions of their apertures were nearly the same.

" No. 4. A similar twelfth, but not quite so good, gave for the bright part, and for the limit of the radial stripes of light,

$$A' = 102°, 0 \ldots; \quad A'' = 122°, 5, \quad . \ . \quad A = 126°, 4.$$

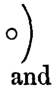
" No. 5. A tenth, said to be of 156°, had the same jagged edge of shadows fading to darkness without any definite termination; the light stripes were fainter than usual.

$$A' = 114°, 6, \quad . \ . \ . \ . \quad A = 156°, 0.$$

In the usual method light could be seen through 159°, but was unbroken only through 115°.

" No. 6. A twelfth, said to be 170°, and in which light was seen through 169°, but for much of that arc so streaky, that I was prepared to find its performance not quite conformable to its aperture, though its workmanship is of the highest order. It presented in the solar apparatus the same appearance as No. 2, with this exception, that the bright central part was not uniform, two-thirds of it being brighter than the rest, and the change rather abrupt; three or four of the radial shadows were also much broader and blacker than the rest. For the clear diameter,

$$A' = 122°, 8, \quad . \ . \ . \ . \ . \quad A = 170°, 0.$$

On looking at this objective, light (and pretty bright too) could be seen even at 90°; which induced me to establish a second microscope, power 41, and fitted with a shade-glass, to examine the image of the sun which was formed in the focus of the objective. This image, whose diameter was 0·0007, was seen through a considerable range as a well-defined circle; but at last a bright curve, probably the edge of one of the cells, was seen to approach it  When it came into contact with this it became deformed, and increasing the angle, it was drawn out into a brilliant line accompanied by several other images, which caused much confusion, but it was quite visible as far as 170°. All, I think, after it touched the image of the cell, were useless.*

" This objective was tried on that most difficult test, the Grammatophora Subtilissima, which it *did* show, but not nearly so well as a sixth of 132°, whose whole aperture was found to be quite perfect: the image which it gave was of a shadowy character, contrasting very unfavourably with the sharp definition of its companion; a result quite obvious if it be considered that the good part of its aperture is only 123°, and that the effect of all the rest must be actually injurious. This was verified by introducing behind the objective a stop

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* This mode of examining the aperture may, in many instances, be useful to opticians, as it can be performed with a camphine lamp. If the examining microscope be fixed on the alidad of the instrument, and that to be examined on a radial slide, light being transmitted through its eye-piece, and both be slided till their focal points be in the axis of rotation (which is ascertained by the image of the flame not moving when the alidad is shifted), it will be found that the image will continue sharp and distinct if the aperture be good, till:—1. It begins to decrease in brightness; 2. Its edge disappears; and 3. Lastly, it vanishes entirely.

Let R be the arc between the points where any of these facts are observed on each side, and a the aperture of ex. microscope's objective:

$$1. \quad \tan \tfrac{1}{2} A = \tan \frac{(R+a)}{2} \times \frac{O}{O-I}.$$

$$2. \quad = \tan \frac{(R-a)}{2} \times \frac{O}{O-I}.$$

$$3. \quad = \tan \frac{(R-a)}{2} \times \frac{O}{O+I}.$$

The first of these is the least accurate.

If the objective have the defect just described, the image retains its brightness, but becomes deformed after a certain angle. In this way I estimated by the formula 2, the good part of No. 6 to be = 122°, 75, not far from the result given in the text. Four other objectives of large aperture gave by it measures according with those of Mr. Lister's method; though, among them also, one of 105 was indistinct for a few degrees.

of 0·125 diameter, which cuts off the irregular part. With this the Angulatum was seen in the most satisfactory manner; but when it was replaced by one carrying a central disc of 0·125, which stops out the good part, it would scarcely show even a trace of lines on the coarsest Pleurosigmata.

“ These facts, I trust, are sufficient to show the necessity of attending not merely to the amount of aperture, but also to its quality. The objectives which I have examined are all of first-rate excellence in the good part of their apertures: I have not named their makers, nor the friends to whose kindness I am indebted for the power of examining so precious a collection, because it might lead some to unjust conclusions respecting the merits of the former. It is from no wish to depreciate the debt of gratitude which we owe them, or to undervalue the wonderful skill which they have shown in correcting aberrations so perfectly as they have done in these very objectives, that I make this communication, but from a wish to point out to *them* a defect which they will be able easily to remedy, and which at present occasionally interferes with their complete success. What its cause is can only be determined by one familiar with the construction of the objectives, but it probably arises from some of the lenses being so small that their edges meet the luminous pencil and reflect false light. I am induced to suspect this from observing that when in No. 6 the first lens was separated from the others by a revolution of the compensating screw beyond its proper adjustment (in which state, however, it would have no definition), the radial shadows disappear altogether, and $A' = 110^\circ, 3$. Reducing the separation by a fourth of the revolution, they are seen, but of no great length, and enveloped in *a blue zone*, which surrounds the bright centre, the latter giving $A' = 139^\circ, 9$. This increase of distance has the effect of stopping out the margins of the other lenses. The disturbance, however, may also be owing to the brass of the cells, but if so the remedy is the same, namely, increasing a little the diameter of the posterior lenses. It is true that this involves an increase of their thickness, and of course a considerable change in the combination. I would also suggest another alteration, in case it be thought desirable still to make objectives of these extreme apertures; that the anterior surface be concave instead of plane. I do not suppose this would much increase the difficulty of the work of correction, and in fact No. 5 was so constructed. To show how much illumination would be gained by this, I have computed the fourth column of the Table, supposing the curvature such that the final incidence is 75°, and the object covered; from which it will be seen, that the difference at the limits is nearly the full power of an objective of 60° aperture, and that it almost compensates for the loss of light due to the cover."

The Rev. Dr. Todd read a Letter which he had received from William H. Harvey, M. D., written in Ceylon in November last, giving an account of his botanical and zoological collections. He also exhibited a restoration by Joseph H. Smith, LL.D., made from a rubbing of an ancient Irish inscribed grave-stone, with an inscription.

Dr. Petrie made some remarks upon the inscription.

The Rev. Dr. Todd presented a Walloon tobacco-box, with several Flemish inscriptions, from the Rev. William Thompson, said to have been found on the person of a soldier slain in the Battle of the Boyne.

Sir W. R. Hamilton having arrived after the period for reading papers, handed in a notice of his being ready to read his paper on the geometrical interpretation of biquaternions.

Dr. Petrie presented an ancient brass cauldron found at Sallow Glin, near Newtown, county of Kerry, from William Sandes, Esq., forwarded by Henry Stokes, Esq.